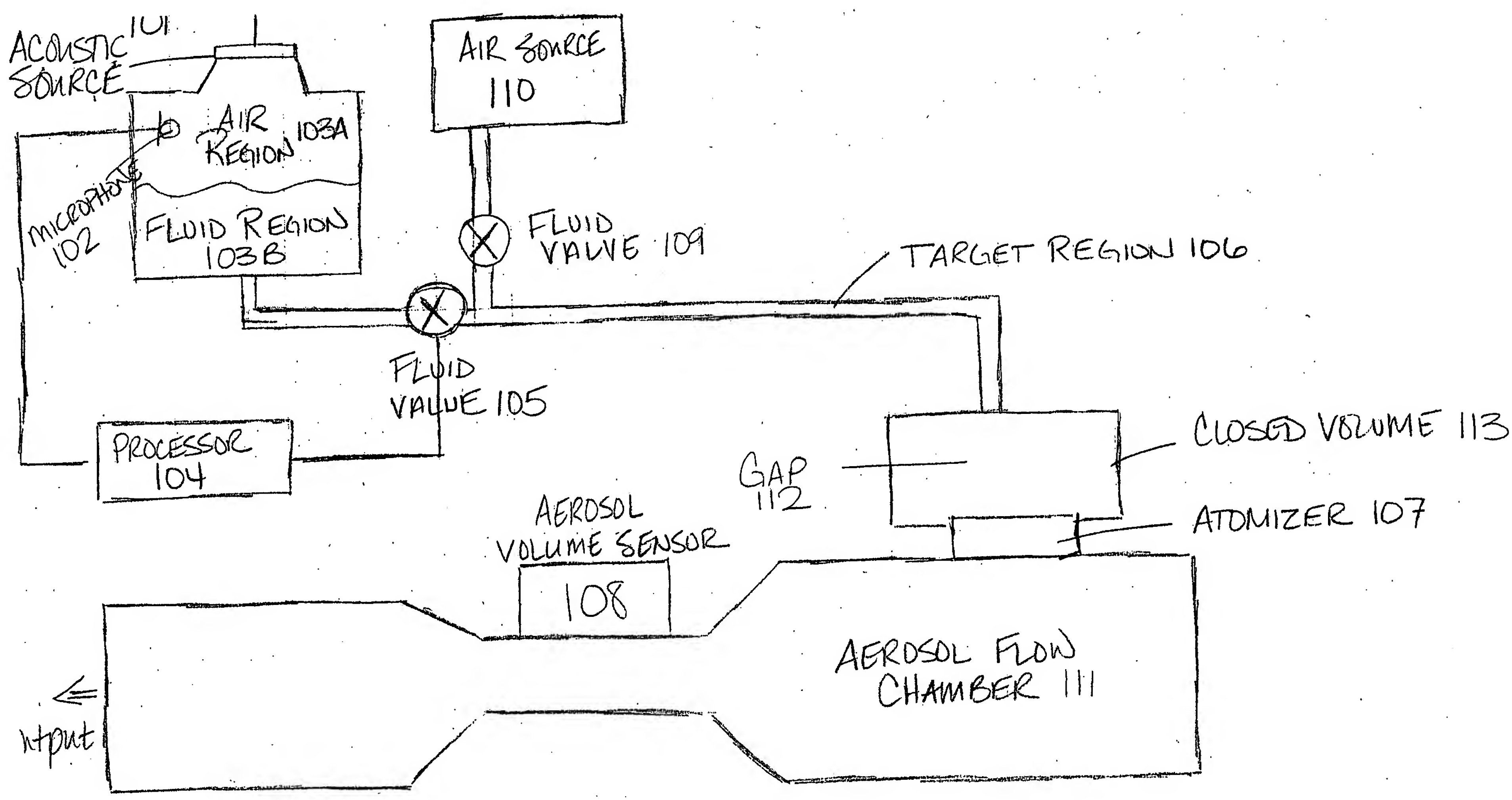
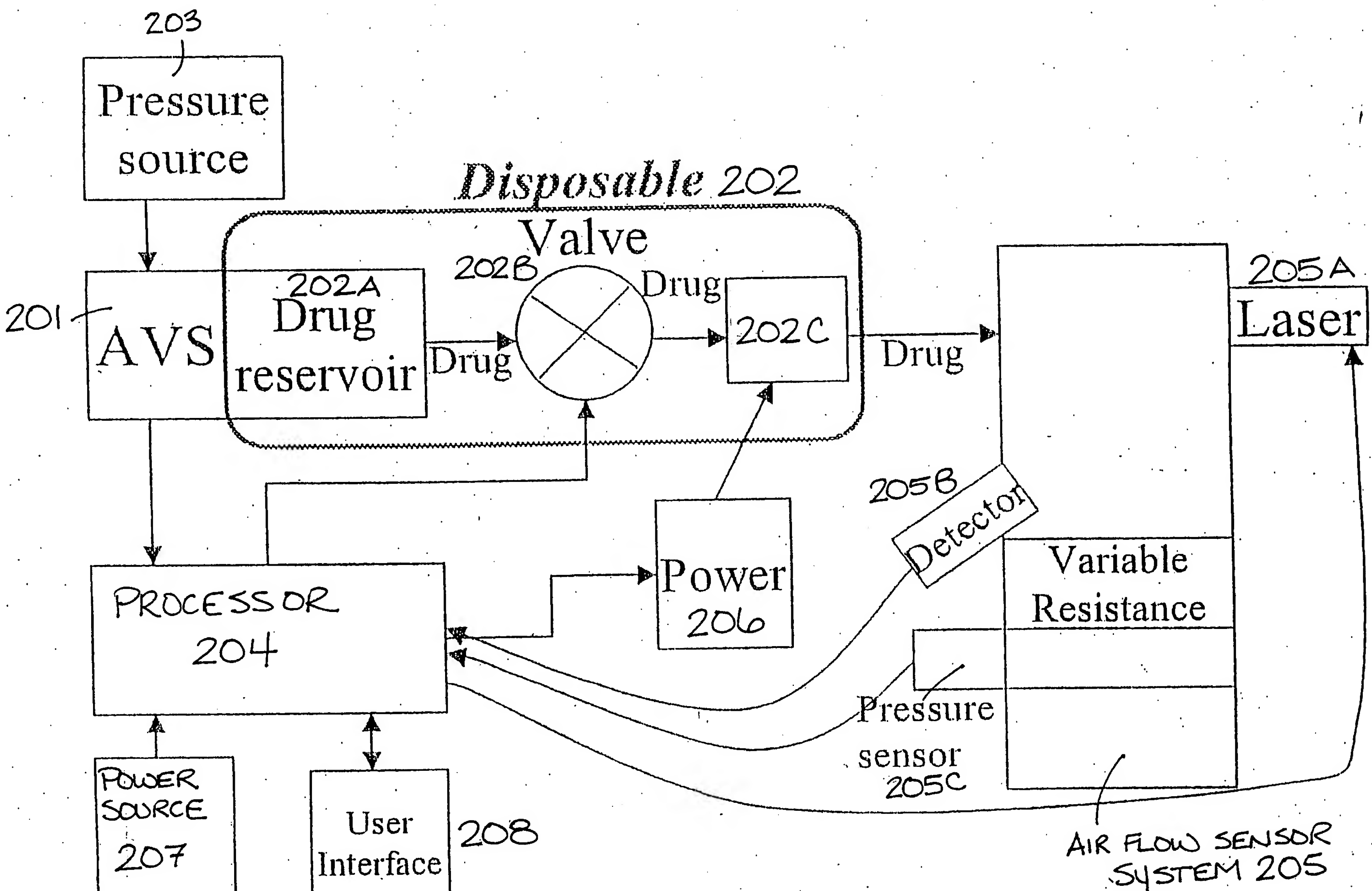

ACOUSTIC SOURCE 101
AIR REGION 103A
MICROPHONE 102
FLUID REGION 103B
AIR SOURCE 110
FLUID VALVE 109
TARGET REGION 106
FLUID VALUE 105
PROCESSOR 104
CLOSED VOLUME 113
GAP 112
ATOMIZER 107
AEROSOL VOLUME SENSOR
108
AEROSOL FLOW CHAMBER 111
Input

FIGURE 1



203
Pressure source
Disposable 202
Valve
201
AVS
202A
Drug reservoir
202B
Drug
Drug
202C
Drug
205A
Laser
205B
Detector
Variable Resistance
PROCESSOR 204
Power 206
Pressure sensor 205C
POWER SOURCE 207
User Interface
208
AIR FLOW SENSOR SYSTEM 205

FIGURE 2

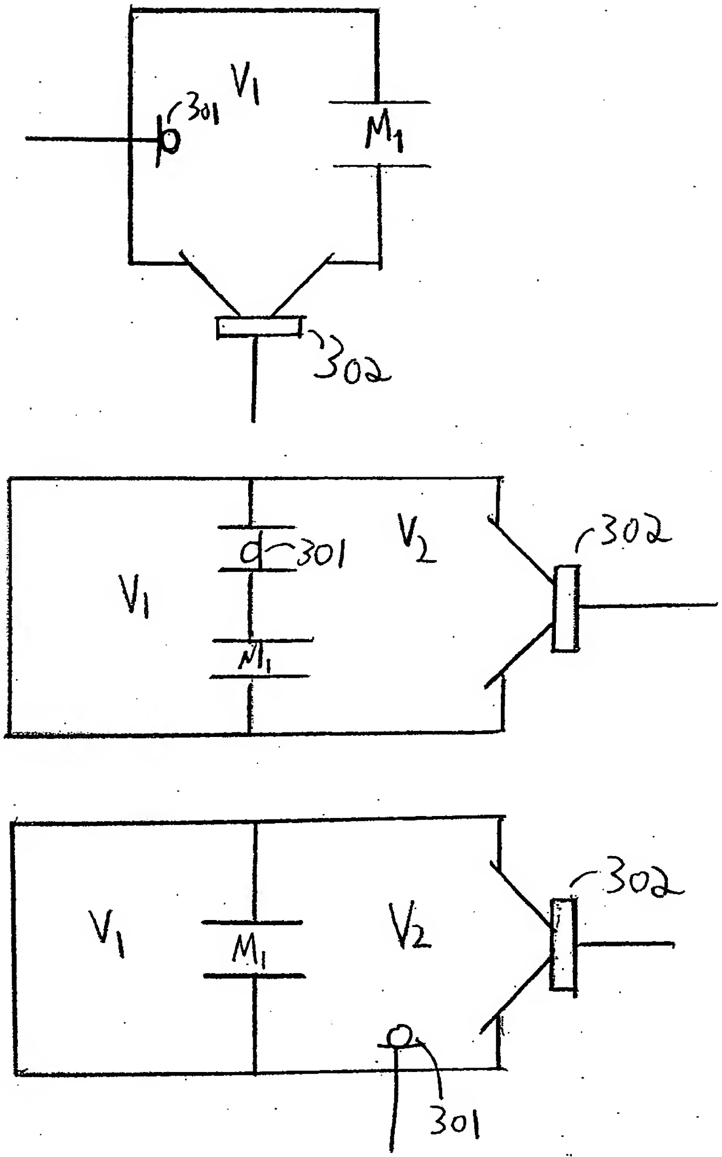


Figure 3

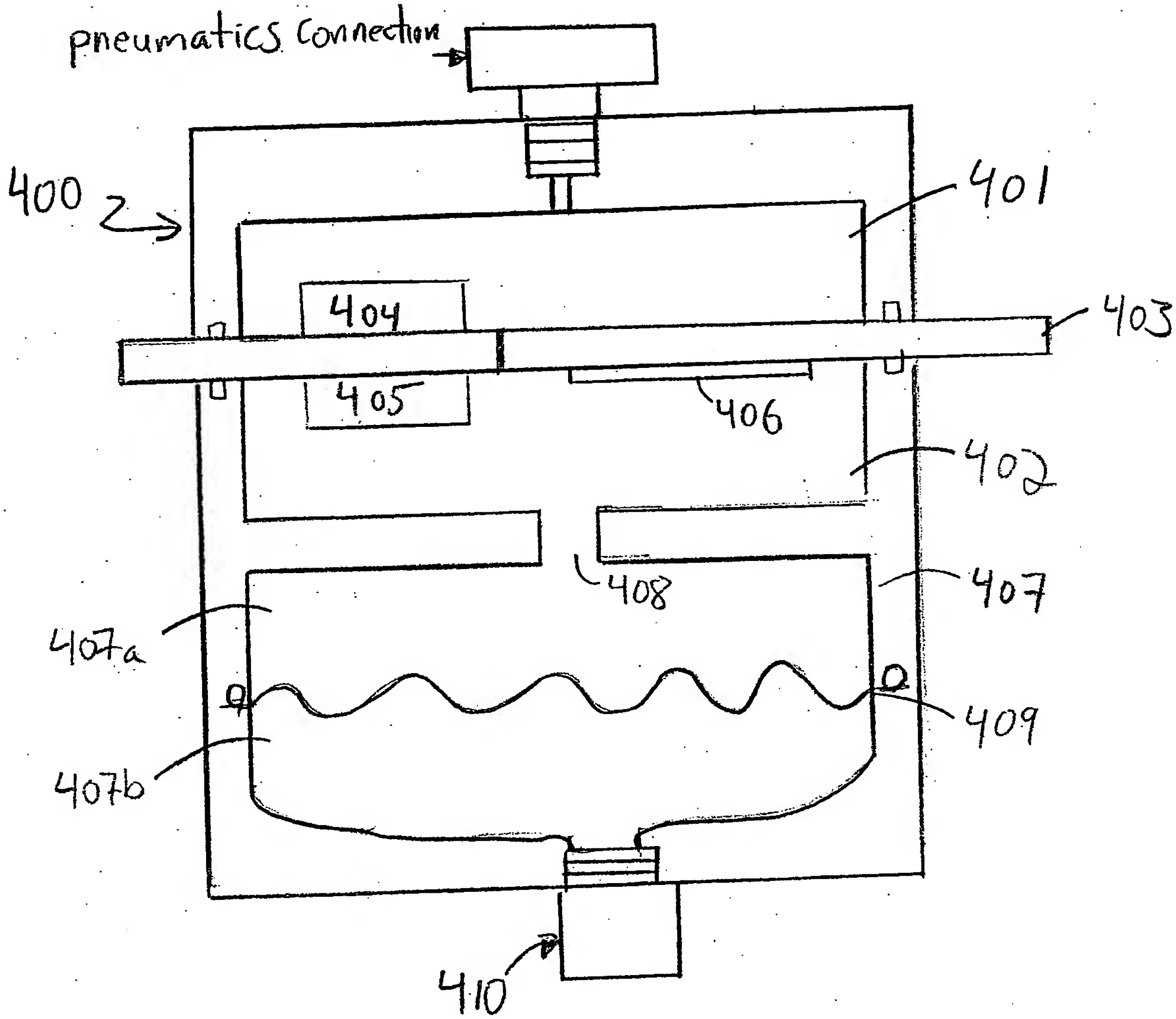
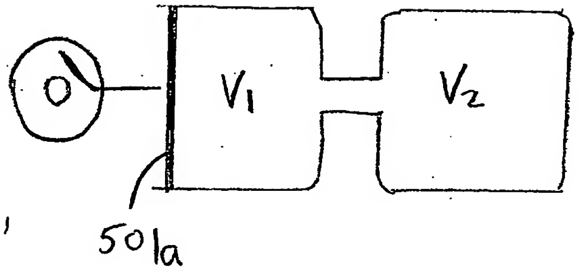
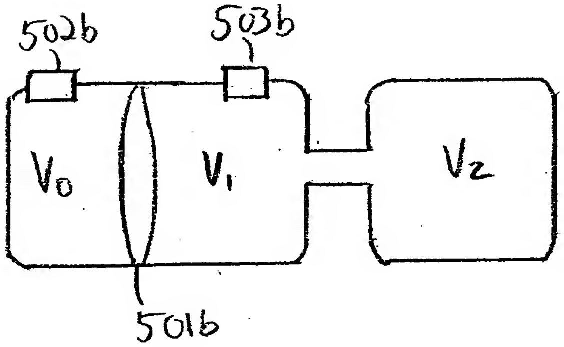

pneumatics connection
400
401
403
404
405
406
402
408
407
407a
409
407b
410

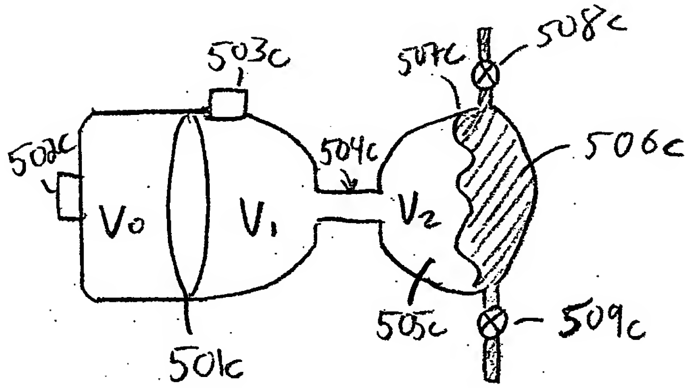
Figure 4



5a



5b



5c

Figure 5

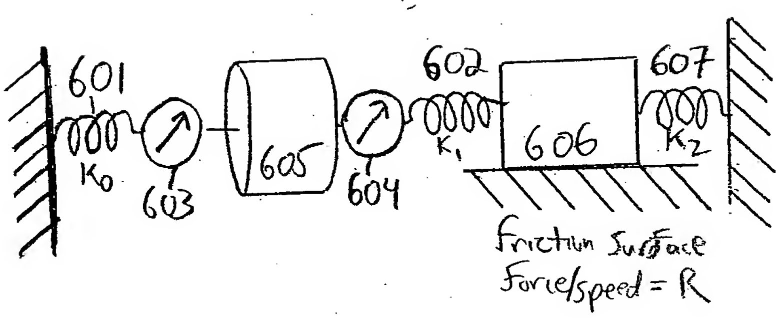

601
602
607
Ko
K1
K2
603
604
605
606
Friction Surface
Force/speed = R

Figure 6

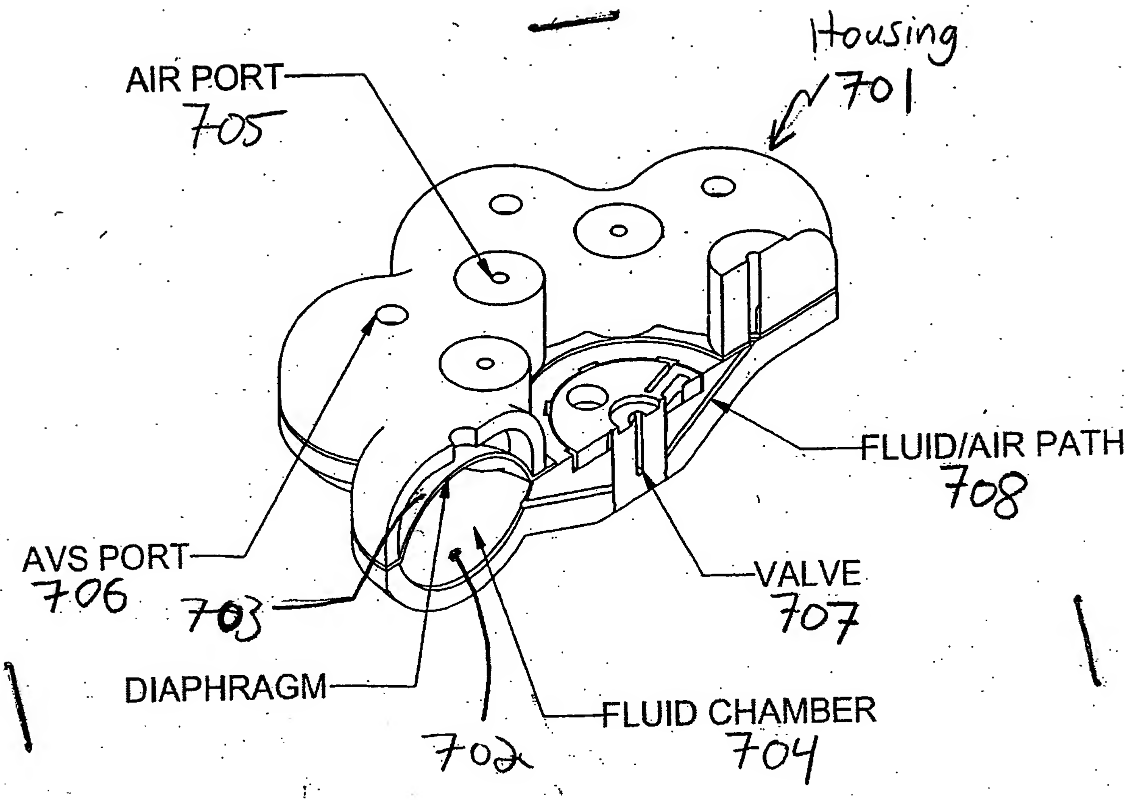

Housing
701
AIR PORT
705
FLUID/AIR PATH
708
AVS PORT
706
703
VALVE
707
DIAPHRAGM
702
FLUID CHAMBER
704

Figure 7

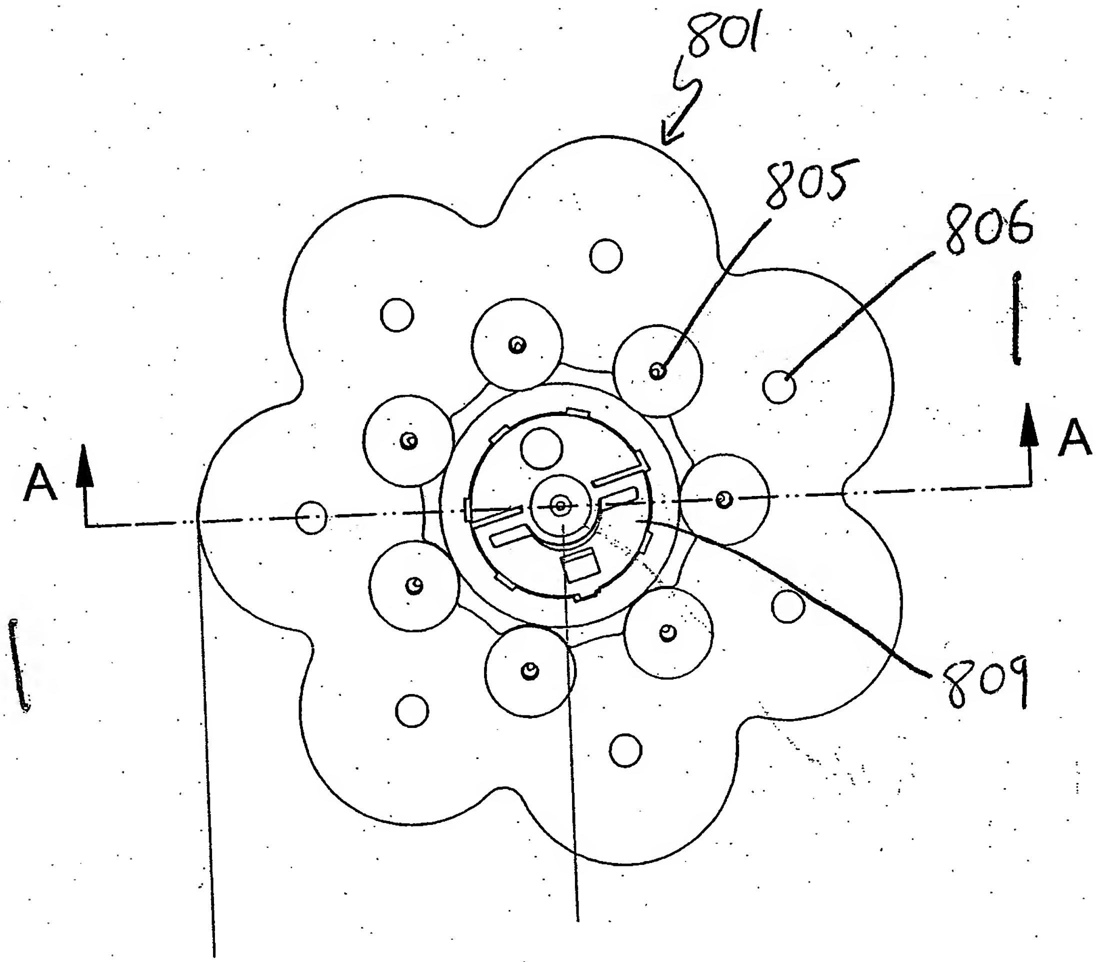


Figure 8

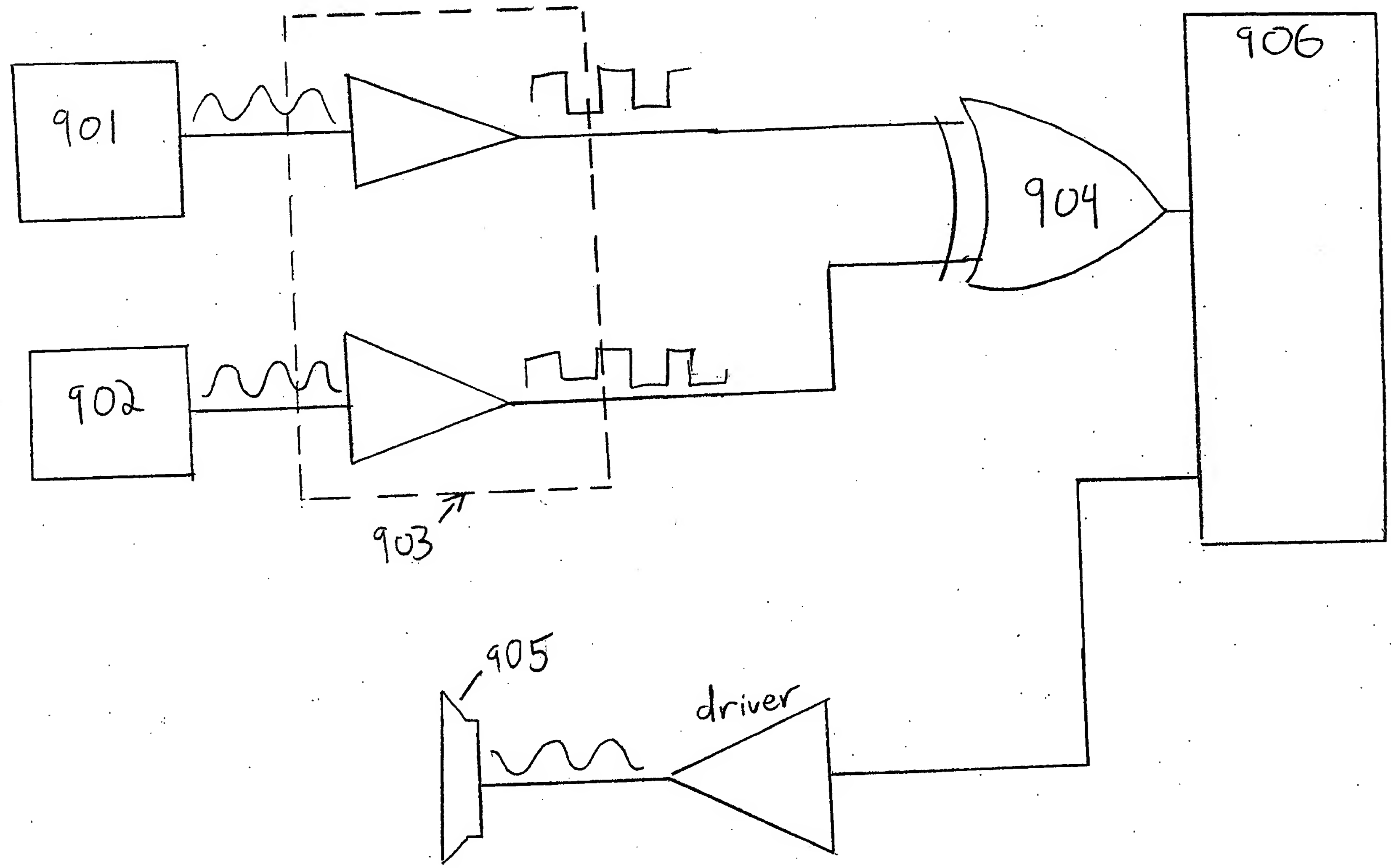


Figure 9

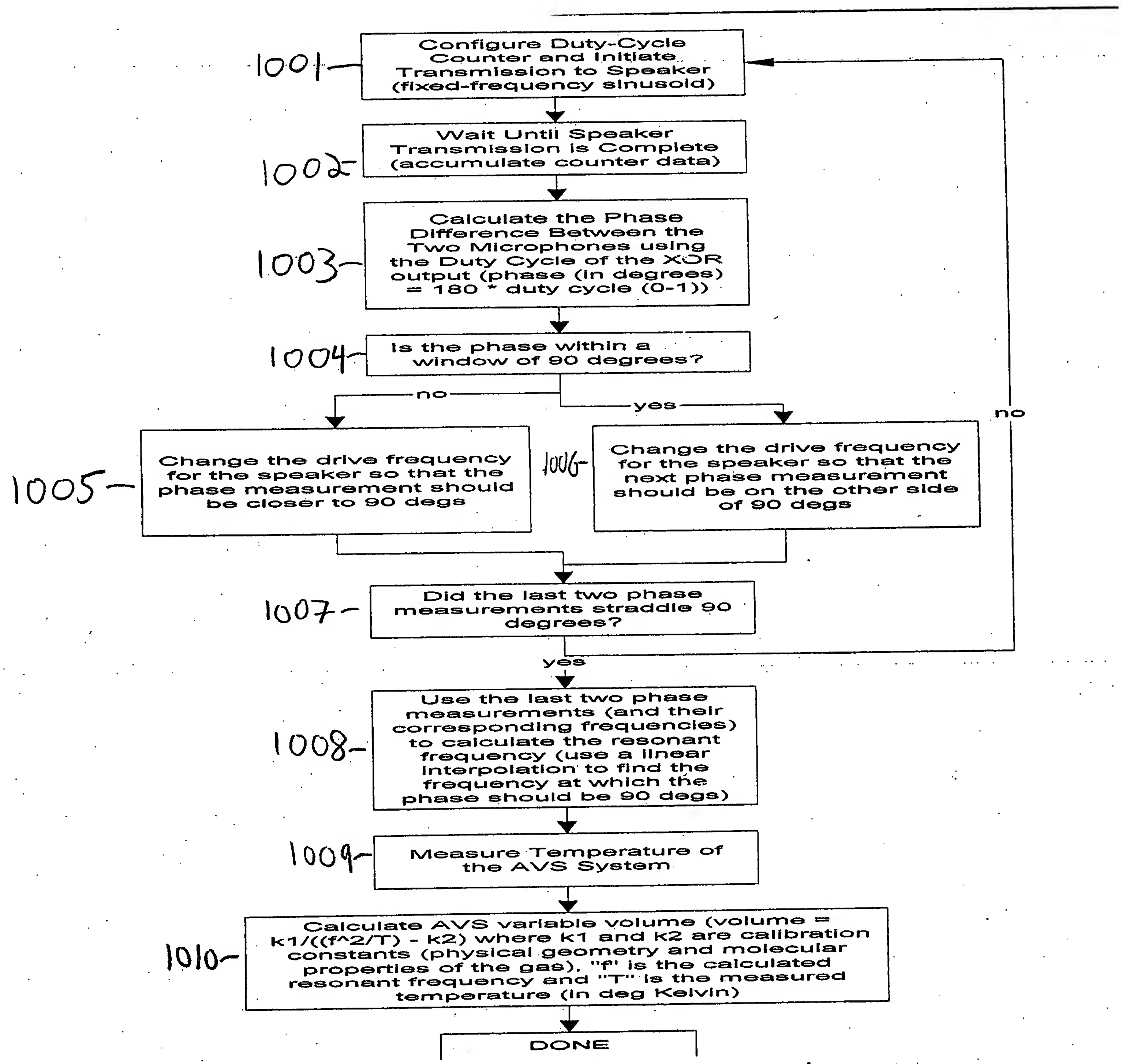

1001
Configure Duty-Cycle Counter and Initiate Transmission to Speaker (fixed-frequency sinusoid)
1002
Wait Until Speaker Transmission is Complete (accumulate counter data)
1003
Calculate the Phase Difference Between the Two Microphones using the Duty Cycle of the XOR output (phase (in degrees) = 180 * duty cycle (0-1))
1004
Is the phase within a window of 90 degrees?
no
yes
1005
Change the drive frequency for the speaker so that the phase measurement should be closer to 90 degs
1006
Change the drive frequency for the speaker so that the next phase measurement should be on the other side of 90 degs
1007
Did the last two phase measurements straddle 90 degrees?
no
yes
1008
Use the last two phase measurements (and their corresponding frequencies) to calculate the resonant frequency (use a linear interpolation to find the frequency at which the phase should be 90 degs)
1009
Measure Temperature of the AVS System
1010
Calculate AVS variable volume (volume = k1/((f^2/T) - k2) where k1 and k2 are calibration constants (physical geometry and molecular properties of the gas), "f" is the calculated resonant frequency and "T" is the measured temperature (in deg Kelvin)
DONE

Figure 10

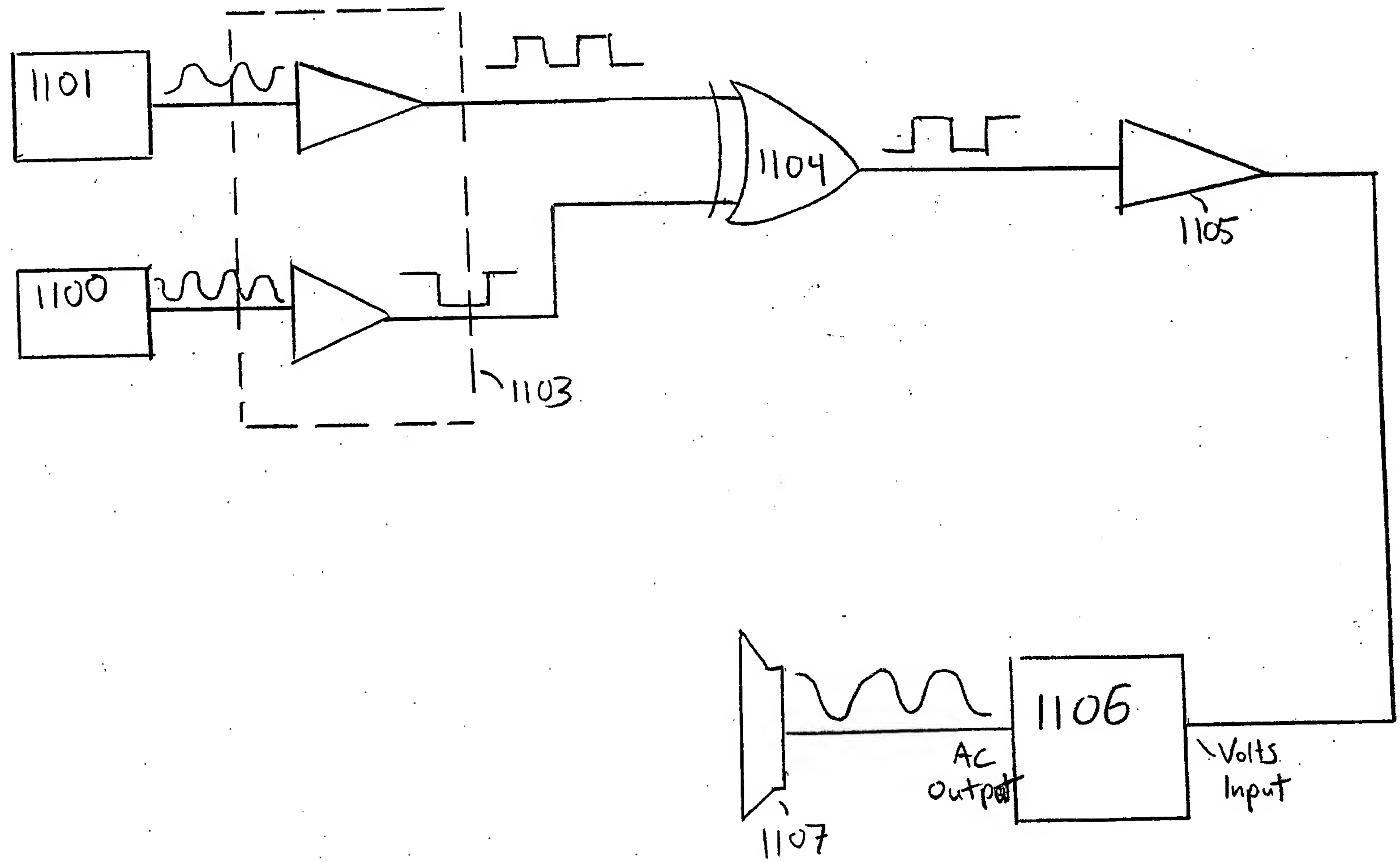


Figure 11

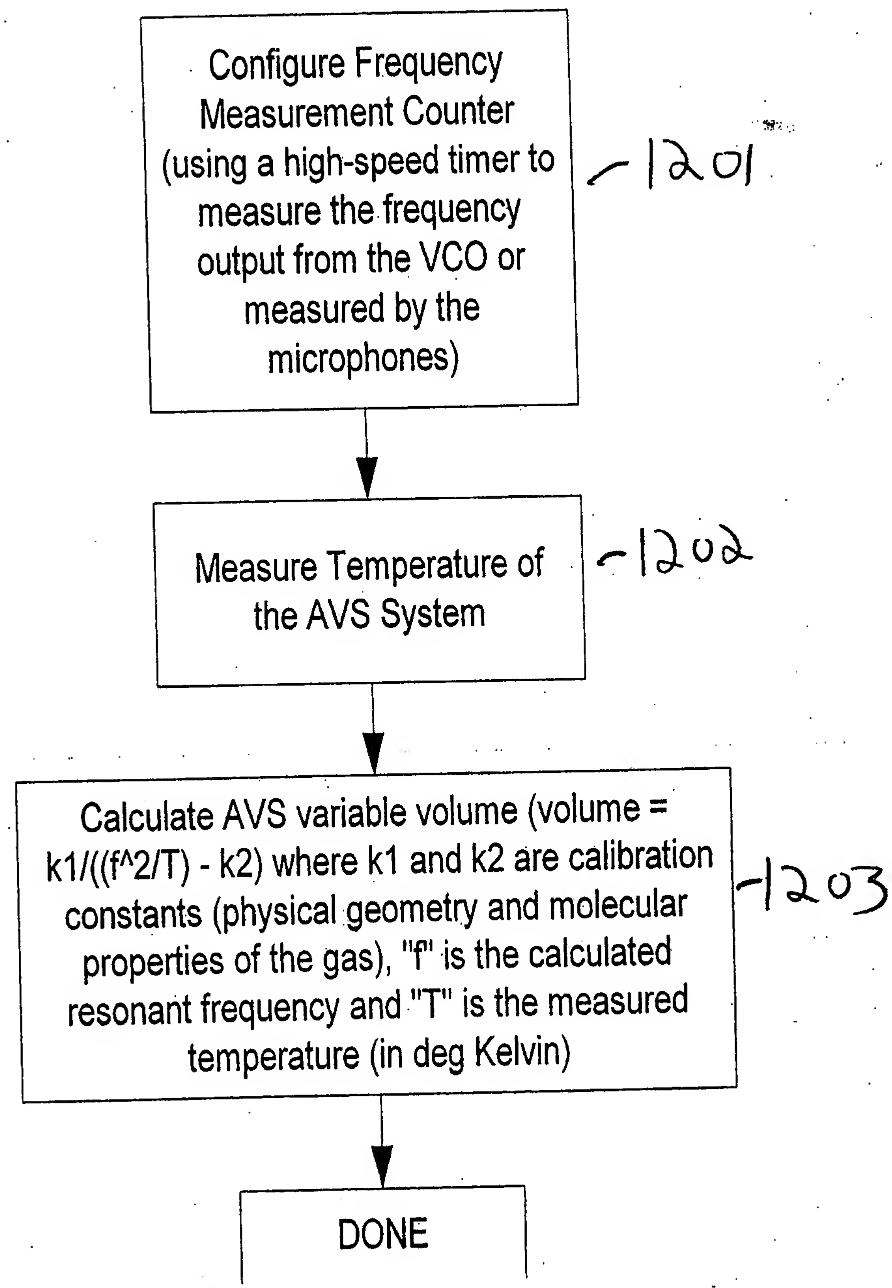
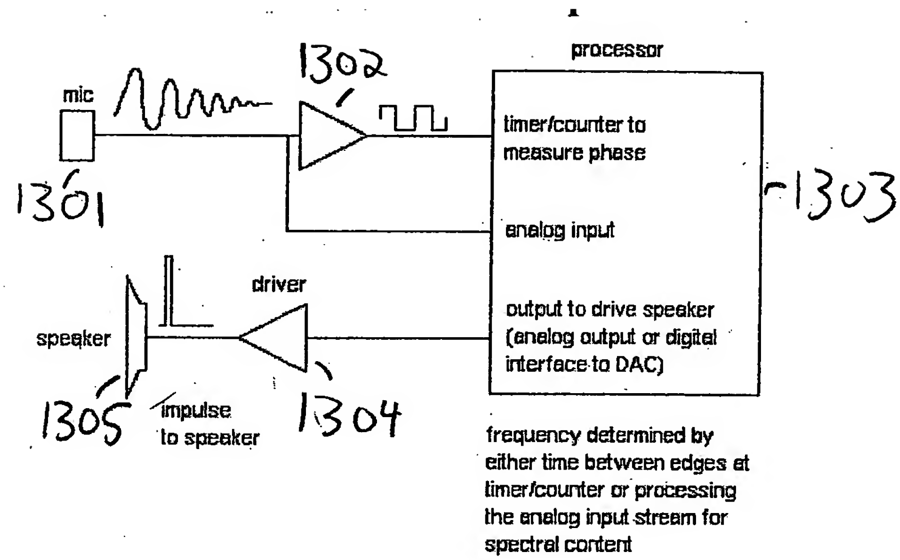

Configure Frequency Measurement Counter (using a high-speed timer to measure the frequency output from the VCO or measured by the microphones)
1201
Measure Temperature of the AVS System
1202
Calculate AVS variable volume (volume = k1/((f^2/T) - k2) where k1 and k2 are calibration constants (physical geometry and molecular properties of the gas), "f" is the calculated resonant frequency and "T" is the measured temperature (in deg Kelvin)
1203
DONE

FIGURE 12



processor
mic
1302
timer/counter to measure phase
1301
1303
analog input
driver
speaker
output to drive speaker (analog output or digital interface to DAC)
1305
impulse to speaker
1304
frequency determined by either time between edges at timer/counter or processing the analog input stream for spectral content

Figure 13

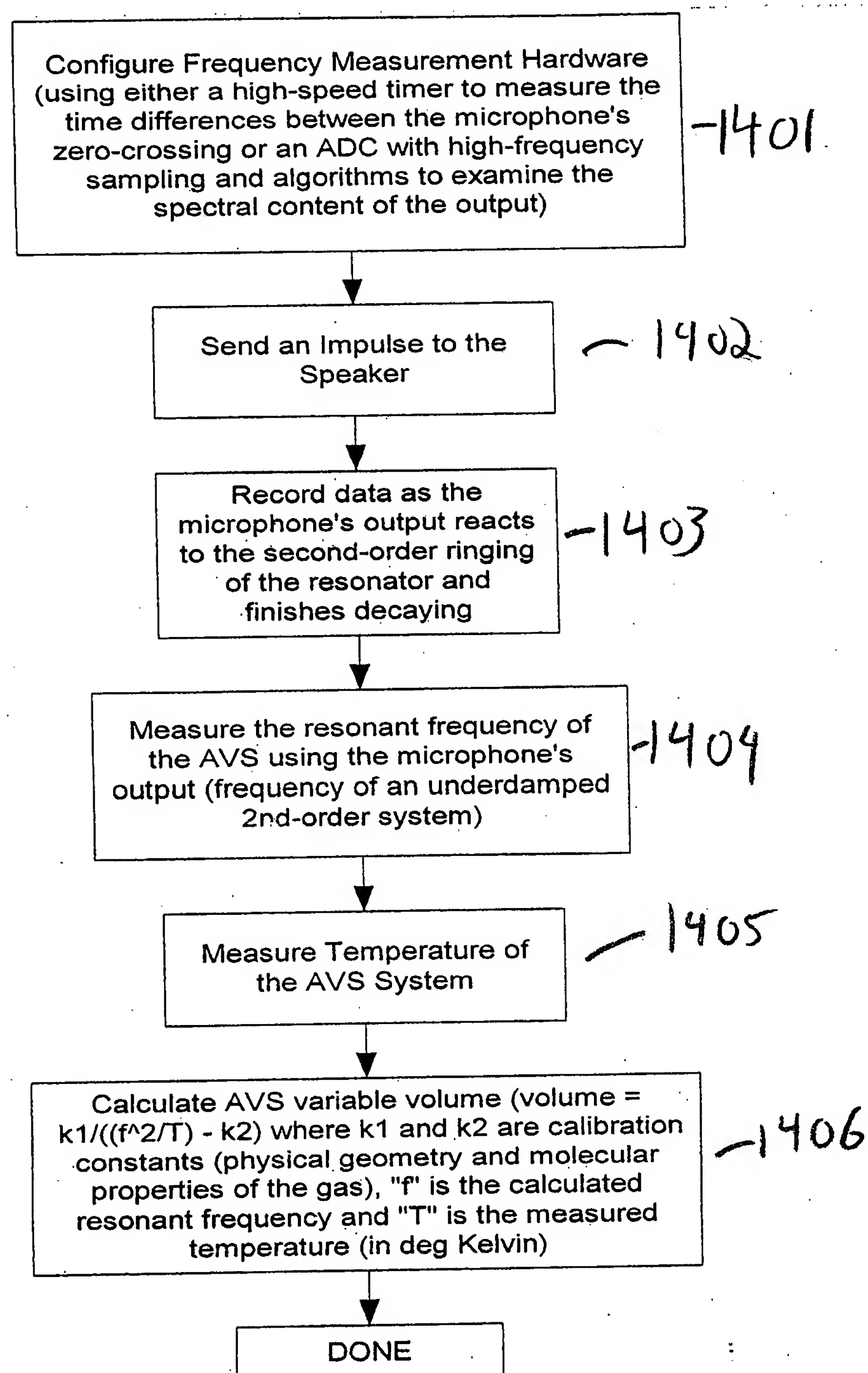

Configure Frequency Measurement Hardware (using either a high-speed timer to measure the time differences between the microphone's zero-crossing or an ADC with high-frequency sampling and algorithms to examine the spectral content of the output)
1401
Send an Impulse to the Speaker
1402
Record data as the microphone's output reacts to the second-order ringing of the resonator and finishes decaying
1403
Measure the resonant frequency of the AVS using the microphone's output (frequency of an underdamped 2nd-order system)
1404
Measure Temperature of the AVS System
1405
Calculate AVS variable volume (volume = k1/((f^2/T) - k2) where k1 and k2 are calibration constants (physical geometry and molecular properties of the gas), "f" is the calculated resonant frequency and "T" is the measured temperature (in deg Kelvin)
1406
DONE

Figure 14

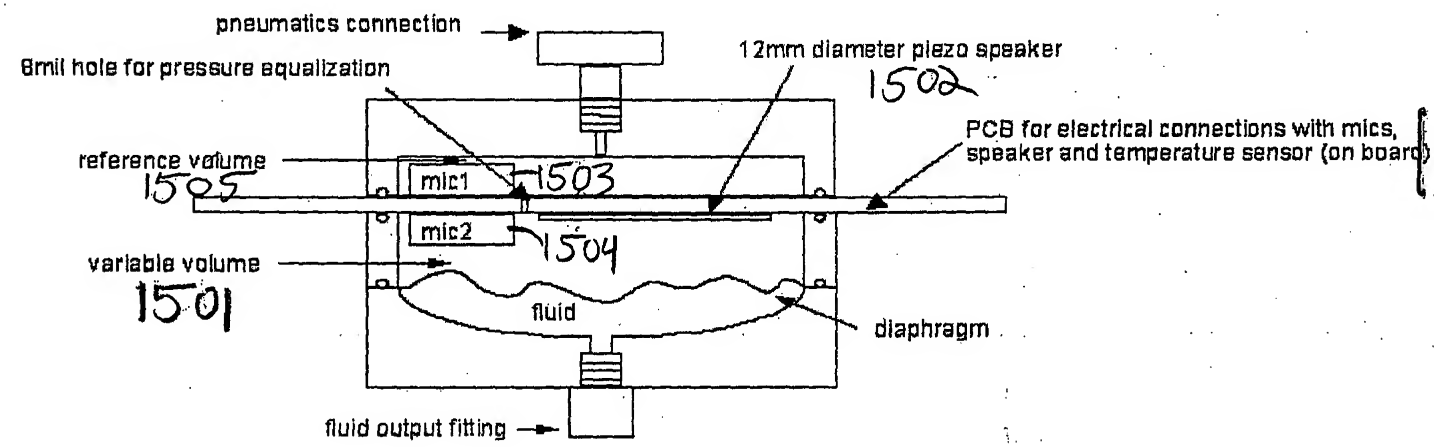

pneumatics connection
8mil hole for pressure equalization
12mm diameter piezo speaker
1502
PCB for electrical connections with mics,
speaker and temperature sensor (on board)
reference volume
1505
mic1
1503
mic2
1504
variable volume
1501
fluid
diaphragm
fluid output fitting

Figure 15

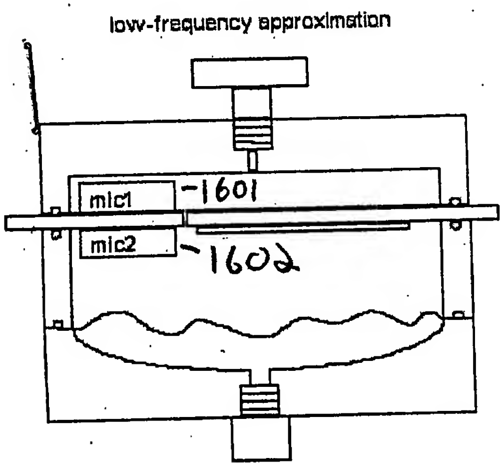


Figure 16

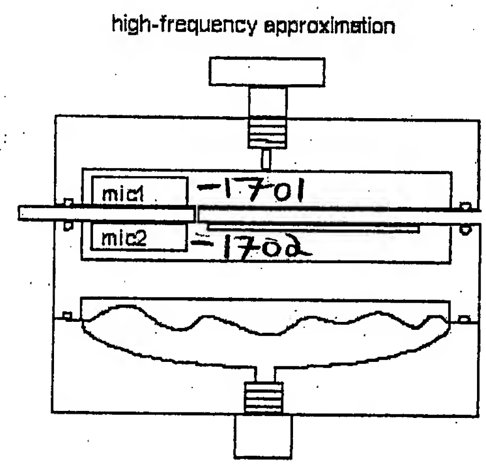


Figure 17

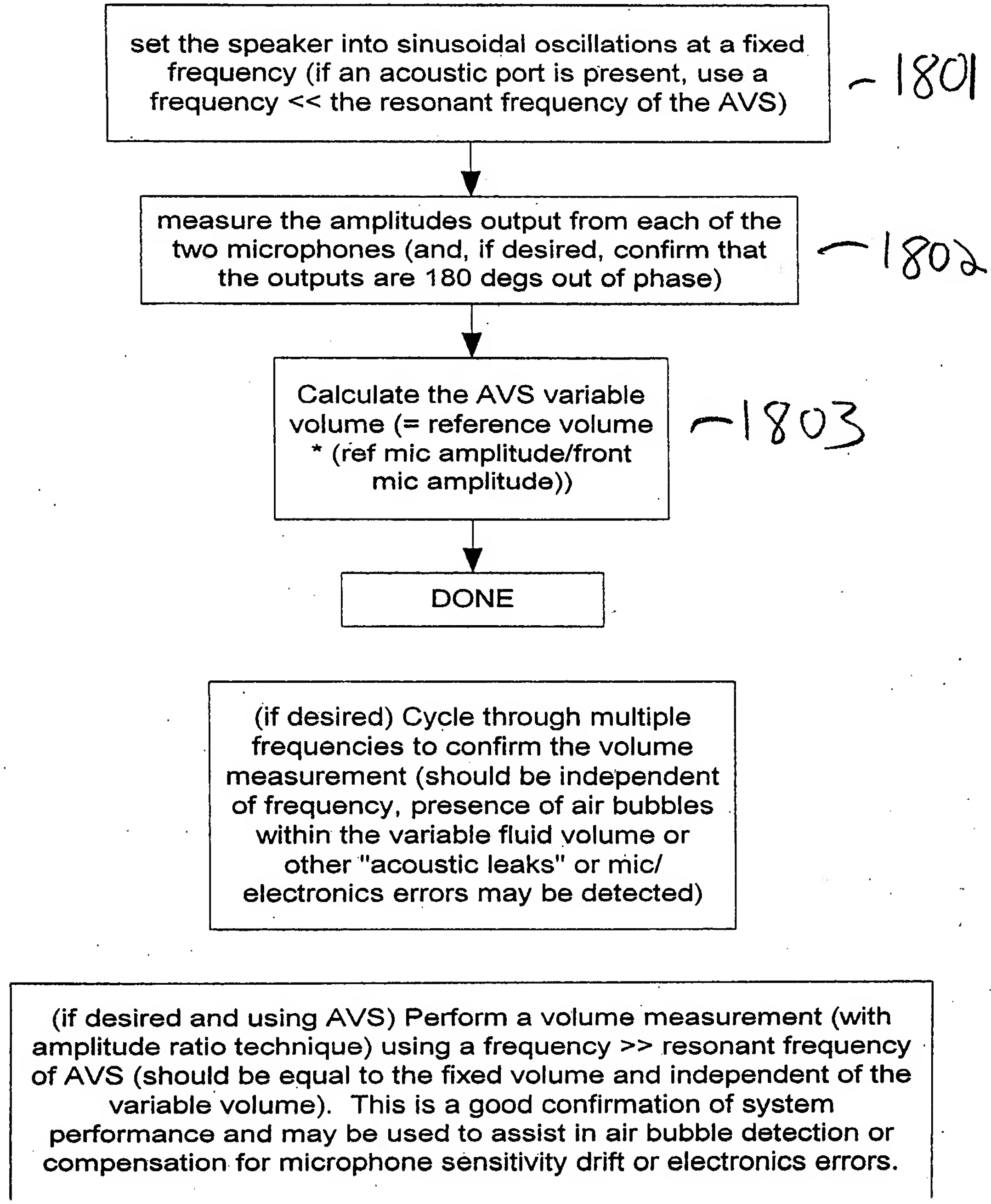

set the speaker into sinusoidal oscillations at a fixed frequency (if an acoustic port is present, use a frequency << the resonant frequency of the AVS)
1801
measure the amplitudes output from each of the two microphones (and, if desired, confirm that the outputs are 180 degs out of phase)
1802
Calculate the AVS variable volume (= reference volume * (ref mic amplitude/front mic amplitude))
1803
DONE
(if desired) Cycle through multiple frequencies to confirm the volume measurement (should be independent of frequency, presence of air bubbles within the variable fluid volume or other "acoustic leaks" or mic/ electronics errors may be detected)
(if desired and using AVS) Perform a volume measurement (with amplitude ratio technique) using a frequency >> resonant frequency of AVS (should be equal to the fixed volume and independent of the variable volume). This is a good confirmation of system performance and may be used to assist in air bubble detection or compensation for microphone sensitivity drift or electronics errors.

Figure 18